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Understanding the optimization of the emitter coverage in BC-BJ solar cells

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Abstract

In this work, by exploiting two-dimensional (2-D) TCAD numerical simulations, we performed a study of optimum emitter coverage ratio (R_{opt}) to reach maximum performance on back contact-back junction (BC-BJ) solar cells. R_{opt} exhibits a strong dependence on pitch, emitter and back surface field (BSF) doping and bulk resistivity, ranging between 0.6 and 0.95. By fixing BSF doping, emitter doping and bulk resistivity, BSF and emitter width can be optimized independently one another. The optimum BSF width and the optimum emitter width are given by a trade-off between series resistance and electrical shading losses. From the design perspective, focusing on optimizing the BSF and emitter width is more effective than optimizing R at fixed pitch or BSF width.

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Keywords: back contact; back junction; solar cells; BC-BJ; TCAD;

1. Introduction

Silicon-based back contact-back junction (BC-BJ) solar cell has been demonstrated particularly promising concept in order to improve the conversion efficiency (currently more than 24% [1],[2]) because of its evident advantages, such as the absence of front contact, elimination of shadowing losses and the simplification of cell interconnection at module level. An important design parameter of BC-BJ solar cell is the emitter coverage R, defined as the pitch fraction occupied by the emitter width. Several works have suggested different optimum values of emitter coverage ratio (R_{opt}) to reach maximum efficiencies [3], [4], ranging between 0.7 and 0.8. This optimum value is explained by electrical shadow and series resistance losses balance [5]. The aim of this work is to

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understand the dependence of R_{opt} on the main physical and geometrical parameters of BC-BJ solar cells by exploiting TCAD simulations.

2. Simulation methodology

Fig. 1 illustrates the simulated symmetry element used in this work calibrated as 200 µm-thick floating zone (FZ) cSi n-type substrate. The doping profiles in back surface field (BSF), front surface field (FSF) and emitter are Gaussian functions of the spatial coordinate featuring the peak located at the edge of the interface and a junction depth of 2 µm for BSF and emitter and of 1µm for FSF region. The front and back surfaces are coated by a double-layer anti-reflective coating (ARC) composed by Si_3N_4 and SiO_2. Front interface is texturized by regular upright pyramids featuring a 10 µm base, while back interface is planar.

The physical models have been calibrated by using the state-of-the-art parameterizations in [6] described on [7]. For all the simulations we used the standard AM1.5G spectrum (1000 W/m^2), FSF peak doping concentration equal to 2.51x10^{18} cm^{-3}, and a gap of 5 µm. A set of experiments was performed considering the following parameter ranges: emitter and BSF doping peak from 1x10^{18} to 1x10^{21} cm^{-3}, BSF width from 55 µm to 300 µm, emitter width from 90 µm to 1600 µm, two different bulk resistivity values of 1 Ω-cm and 10 Ω-cm. The main investigated parameter is R_{opt}, which represents the value of R required to maximize the efficiency for each analysis, performed by fixing some parameters and varying the others. Therefore, R_{opt} is a relative optimum and not the absolute optimum.

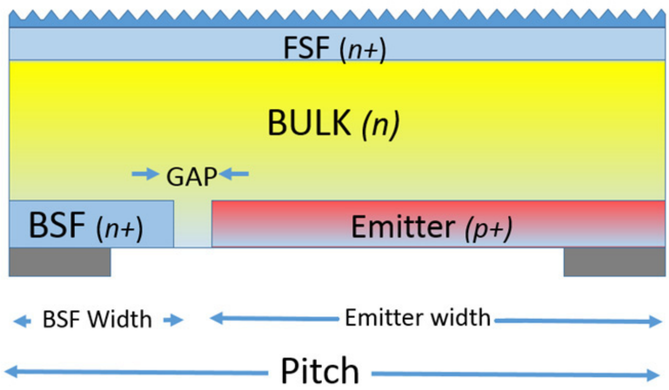

Fig. 1. Sketch of the symmetry element of BC-BJ solar cell used in the simulations.

3. Results and discussion

Fig. 2 illustrates R_{opt} as a function of emitter and BSF doping keeping constant pitch and emitter width, for different values of BSF width and bulk resistivity. R_{opt} ranges in a wide interval between 0.6 and 0.95. According to [7], in terms of efficiency, there are optimum values of BSF and emitter doping levels, which do not depend one another and are quite insensitive to the cell geometrical parameters and to the bulk resistivity. In the rest of this paper, in the case of a bulk resistivity of 1 Ω-cm (10 Ω-cm) we used the optimum BSF doping of 2.51x10^{20} cm^{-3} (6.31x10^{19} cm-3) and the optimum emitter doping of 1.58x10^{19} cm^{-3}.

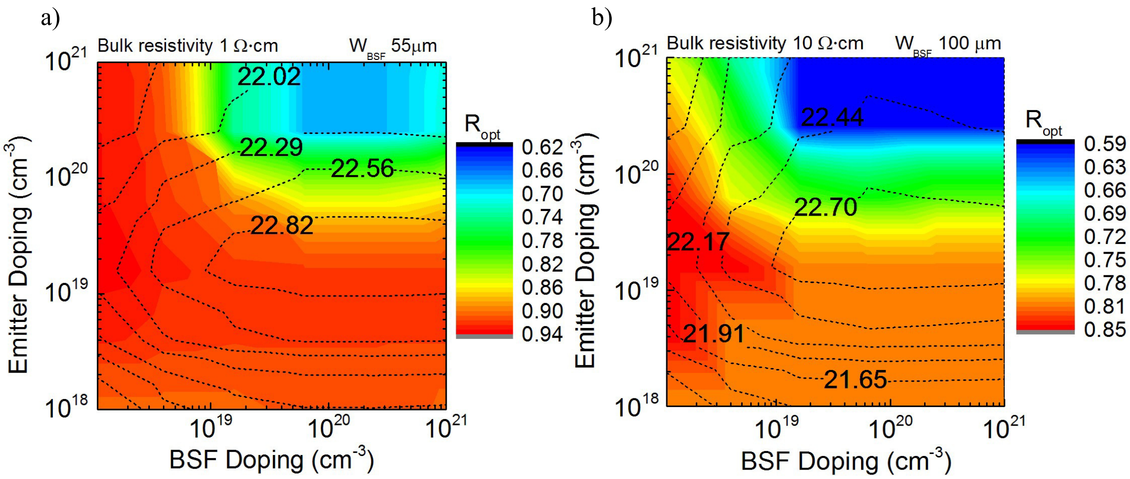

Fig. 2. (a) Simulated R_{opt} dependence from BSF and emitter doping; (b) dotted lines illustrate calculated efficiencies.

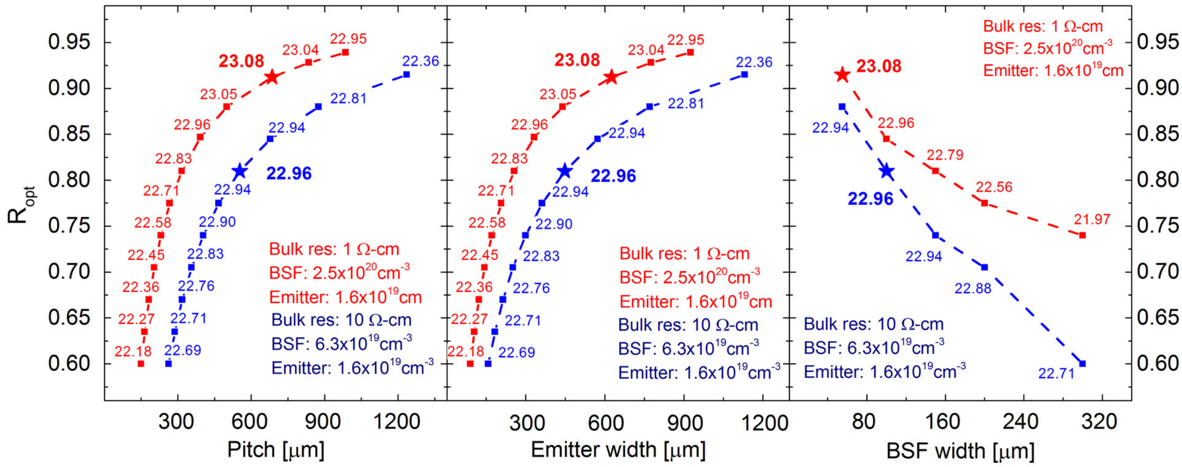

Fig. 3. Calculated R_{opt} for different values of pitch (left), emitter width (middle) and BSF width (right). Numbers above points are calculated efficiencies.

Fig. 3 illustrates results from simulations that were performed to analyze R_{opt} as a function of pitch, BSF and emitter width for fixed doping levels on emitter and BSF and for two different values of bulk resistivity. R_{opt} significantly increases with pitch and emitter width, while it significantly decreases with BSF width, ranging again in a wide interval between 0.6 and 0.95. In the case of a bulk resistivity of 1 Ω-cm (10 Ω-cm), the absolute maximum efficiency is 23.08 (22.96) corresponding to R_{opt} of 0.91 (0.81).

Fig. 4 illustrates efficiency as a function of BSF and emitter width keeping constant BSF and emitter doping levels for different values of bulk resistivity. It is worth noting that the BSF and the emitter width can be optimized independently one another. In the case of a bulk resistivity of 1 Ω-cm (10 Ω-cm), the optimum BSF width is 55 μm (100 μm) and the optimum emitter width is 646 μm (448 μm). These optimum values are obtained as a trade-off between electrical shading and series resistance effects. The electrical shading losses decrease by increasing the emitter width and by reducing the BSF width, while the series resistance losses increase by increasing the emitter width and by reducing the BSF width. By comparing Fig. 4a and 4b, it is evident that by increasing the bulk resistivity, the optimum BSF width increases due to the stronger contribution of bulk to total series resistance losses.

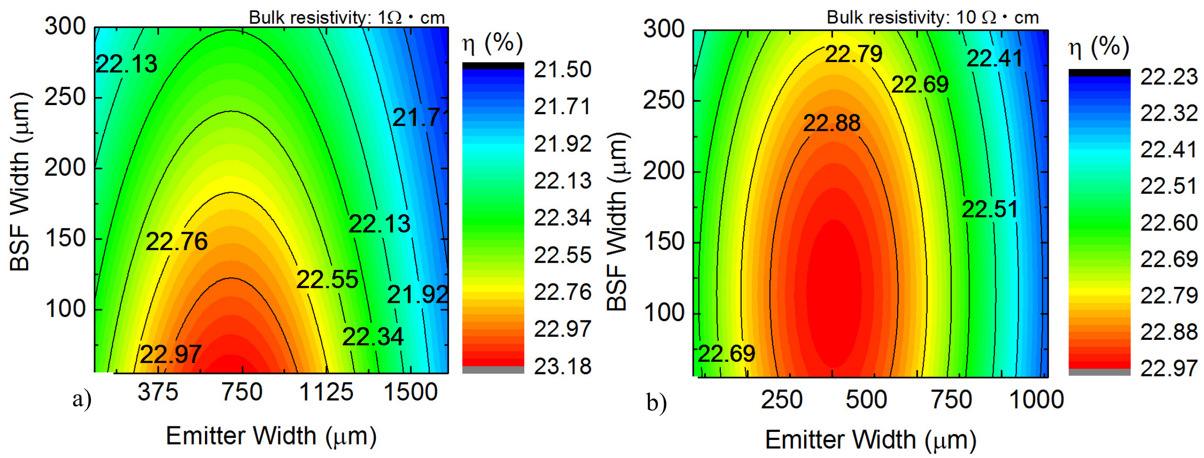

Fig. 4. Simulated efficiency dependence from BSF and emitter width for a bulk resistivity of 1 Ω-cm (a) and 10 Ω-cm (b). In both cases, the BSF and the emitter width can be optimized independently one another.

4. Conclusions

In this study, we reported that R_{opt} exhibits a strong dependence on emitter and BSF doping levels, pitch, emitter and BSF width, and bulk resistivity, ranging between 0.6 and 0.95. From the geometry design perspective, it is more effective optimizing independently the BSF and emitter width than optimizing R at fixed pitch or BSF width. In the case of a bulk resistivity of 1 Ω-cm (10 Ω-cm), we obtained an absolute maximum efficiency of 23.08 (22.96) for BSF width of 55 μm (100 μm) and emitter width of 646 μm (448 μm), which give a pitch of 706 μm (553 μm) and R_{opt} of 0.91 (0.81).

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